

## PROJECT SUMMARIES

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### NOISE AND INTERFERENCE AFFECTING THE PERFORMANCE OF EXISTING AND PROPOSED COMMUNICATION SYSTEMS

**Richard W. Adler, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Federal Communication Commission**

**OBJECTIVE:** To assess and report to the FCC the current state of knowledge about the electromagnetic noise and interference that affects the performance of existing and future wireless systems.

**SUMMARY:** The effort involves (1) a literature survey of the noise environment and (2) a preliminary definition of the modeling, simulation and measurement requirements for evaluating the effects of the noise on communication systems.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Radio Noise, Interference, Spectrum Signatures, Bibliographies

### SIGNAL-TO-NOISE ENHANCEMENT PROGRAM

**Richard W. Adler, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Security Group**

**OBJECTIVE:** To define factors that adversely affect signal reception at receiving sites, determine the primary characteristics of factors, identify all factors, and provide recommendations for effective mitigation actions.

**SUMMARY:** Radio noise from overhead power lines has been identified as the major factor limiting the reception of radio signals at 36 of 37 sites examined. This little recognized factor is seriously limiting the effectiveness of HF, VHF, and UHF intercept systems to collect signals of special interest. The primary properties of this noise have been defined, source location procedures have been devised, and a means to identify source hardware has been generated. This effort has generated a number of technical papers and presentations during the last year. Some related work on signal reception in the microwave ISM bands has also been conducted.

#### PUBLICATIONS:

Parker, A.A., Adler, R.W. and Vincent, W.R., *Conducted EMI from an Engineering Model of a DC-to-DC Converter*, Naval Postgraduate School Technical Report, NPS-EC-01-007, June 2001.

#### PRESENTATIONS:

Vincent, W., Adler, R. and Munsch, G., "A Review of Man-Made Radio Noise at 37 HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Munsch, G. and Adler, R., "A Progress Report on a Model for Man-Made Noise at HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Parker, A., Adler, R. and Vincent, W., "Spectrum Signatures of Man-Made Noise," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Parker, A. and Adler, R., "Ambient Signals and Noise in the 915-MHz ISM Band," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

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Vincent, W., Adler, R. and Munsch, G., "Operation of a 2.4 GHz Portable Phone with Noise From a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "The Temporal and Spectral Properties of Radio Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

### **OTHER:**

Parker, A., Adler, R. and Vincent, W., "Parasitic Oscillations from an Active Television Antenna," prepared in cooperation with the Department of Oceanography.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Radio Noise, Interference, Spectrum Signatures

### **DEVELOPMENT OF ALGORITHMS SUPPORTING HARDWARE-IN-THE-LOOP CONTROL OF SYNCHRONOUS MACHINES**

**Robert William Ashton, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center - Carderock Division**

**OBJECTIVE:** This research involves the creation of a DSP platform for developing and testing motor control algorithms. The platform will have hardware-in-the-loop testing capability. The Navy's interest in pursuing an electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor. The proposed research seeks to aid in the developing tools and algorithms to support an initial reduced-scale proof-of-concept demonstration. The demonstration will utilize a three-phase permanent magnet synchronous machine powered by a conventional three-phase voltage source inverter. The investigation will execute a number of tasks, culminating in a set of deliverables.

**DoD KEY TECHNOLOGY AREAS:** Other (Motor Control)

**KEYWORDS:** PWM Inverter, Synchronous Machine, Vector Control, DSP

### **IMPLEMENTATION OF CLOSED-LOOP SYNCHRONOUS MACHINE CONTROL**

**Robert William Ashton, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center - Carderock Division**

**OBJECTIVE:** The proposed research seeks to aid in hardware and software modifications to existing inverters so that various Navy motor loads may be utilized and tested. This research involves the implementation of closed-loop controls for synchronous machines utilizing multiple inverters of varying power levels to drive Navy motor loads up to 400HP. The Navy's interest in pursuing an electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor and other motor loads. The drive system will be demonstrated utilizing three-phase induction or synchronous machines powered by multiple synchronized three-phase inverters. The investigator will execute a number of tasks, culminating in a set of deliverables.

**DoD KEY TECHNOLOGY AREAS:** Other (Motor Control)

**KEYWORDS:** PWM Inverter, Synchronous Machine, Vector Control, DSP

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### INTEGRATED FIGHT-THROUGH POWER AND ADVANCED POWER CONVERTER MODULES

**Robert William Ashton, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Surface Warfare Center - Philadelphia**

**OBJECTIVE:** The proposed research seeks to aid in developing tools and algorithms to support an initial reduced-scale proof-of-concept demonstration.

**SUMMARY:** This research involves the creation of a DS platform for developing and testing motor control algorithms. The platform will have hardware-in-the-loop testing capability. The Navy's interest in pursuing an electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor. The demonstration will utilize a three-phase permanent magnet synchronous machine powered by a conventional three-phase voltage source inverter. The investigation will execute a number of tasks, culminating in a set of deliverables.

This research involves the engineering design of advanced power conversion modules under current Navy development. This task will require the investigation of available power converter design options. Additionally, assistance in the design and development of advanced reconfigurable zonal electric distribution system hardware will be provided in the form of testing, debugging and documentation. Support includes conducting appropriate tests, analyzing/evaluating technical documentation/data, and providing comments. The principal investigator shall attend technical meetings, as required, and provide monthly status reports. Travel to CDNSWC-SSES Philadelphia shall be required to implement the above objectives.

This research concentrated on specific issues surrounding the Land Based Engineering Site (LBES) in Philadelphia. The investigator was tasked with the evaluation of data from test runs for a number of Power Converter Modules (PCM) ranging from 250kW to 19MW. Test results were analyzed and used by the investigator to aid in making recommendations for future PCMs. In addition, three specific failure events took place on the 19MW PWM electric drive unit. Each event was analyzed using the available data including forensics on the components. Reports and presentations were made in Philadelphia and Rugby, England. The results of the investigation have been utilized in redesign efforts by the vendor.

**DoD KEY TECHNOLOGY AREAS:** Other (Electronic Devices, Energy Conversion)

**KEYWORDS:** Power System, Auxiliary Resonant Commutated Pole Inverter, PWM Inverter, Synchronous Machine, Vector Control, DSP

### DESIGN ALGORITHMS FOR SUM-OF-PRODUCTS EXPRESSIONS

**Jon T. Butler, Professor**  
**Department of Electrical and Computer Engineering**  
**Tsutomu Sasao, Kyushu Institute of Technology, Japan**  
**Sponsor: Unfunded**

**OBJECTIVE:** To produce design algorithms for digital logic circuits using sum-of-products expressions.

**SUMMARY:** The design of many logic circuits relies on the simplification of sum-of-products expressions that describe the function realized by the circuit. Efforts this year focused on three aspects of this problem. First, work continued from last year on bi-decomposition of functions. Last year, orthodox functions were identified as a special class of functions for which an efficient divide-and-conquer algorithm produces minimal sum-of-products expressions. This year, collaborative work with NPS Master's student, Birol Ulker, identified families of non-orthodox functions in. Second, shared binary decision diagrams (SBDDs) were successfully applied to multi-output functions, and it was shown that this results in an improvement in circuit compactness of 16%, on the average, over standard binary decision diagram techniques. Third, a new type of programmable logic device was proposed and a study of efficient algorithm for these devices has been initiated. This is collaborative work with Professor Tsutomu Sasao of the Kyushu Institute of Technology.

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### **PUBLICATIONS:**

Matsuura, M., Sasao, T., Butler, J.T. and Iguchi, Y., "Bi-partition of Shared Binary Decision Diagrams," Workshop on Synthesis and System Integration of Mixed Technologies (SASIMI-2001), pp. 172-177, Nara, Japan, 18-19 October 2001.

Sasao, T. and Butler, J.T., "Worst and Best Sum-of-Products Expressions," *IEEE Transactions on Computers*, pp. 935-948, September 2001.

Sasao, T. and Butler, J.T., "On the Minimization of SOPs for Bi-Decomposable Functions," ASP-DAC (Asian Southern Pacific Design Automation Conference), pp. 219-224, Yokohama, Japan, February 2001.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software

**KEYWORDS:** Digital Systems, Compact Circuits, Computer-Aided Design Tools, Sum-of-Products Expressions

### **REED-MULLER CANONICAL EXPANSIONS OF LOGIC FUNCTIONS**

**Jon T. Butler, Professor**

**Department of Electrical and Computer Engineering**

**G.W. Dueck, University of New Brunswick, Canada**

**Sponsor: Unfunded**

**OBJECTIVE:** To improve synthesis techniques for the Reed-Muller canonical representation of logic function.

**SUMMARY:** The Reed-Muller canonical expansion of a logic function uses the Exclusive OR of product terms, where each product term is the AND of variables or their complements. It has been shown that this representation requires fewer product terms, on the average, than standard sum-of-products expressions. The transeunt triangle concept that was introduced earlier has been extended to efficiently realize totally symmetric functions so that it also applies to partially symmetric functions. Efforts have also been expanded to the more general "inconsistent" expansion of functions proposed more than 30 years ago by Martin Cohn. In a collaborative effort with NPS student, Panos Michalopoulos, progress has been made in the understanding of the largest size one can possibly expect of functions in this form.

### **PUBLICATIONS:**

Butler, J.T., Dueck, G.W., Yanushkevich, S.N. and Shmerko, V.P., "On the Number of Generators for Transeunt Triangles," *Discrete Applied Mathematics*, Vol. 108, pp. 309-316, 2001.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software

**KEYWORDS:** Digital Systems, Compact Circuits, Computer-Aided Design Tools, Exclusive OR Sum-of-Products Expressions, Reed-Muller Canonical Expressions

### **COMPONENT MODELING AND SIMULATION EFFORTS FOR A PROPOSED LHD-8 AC ZONAL DISTRIBUTION SYSTEM**

**John G. Ciezki, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center - Carderock Division**

**OBJECTIVE:** The Navy is currently designing the next-generation LHD amphibious ship. Innovations are being proposed for the power distribution system, including zonal AC and a hybrid electric drive. Models of the components and interconnected system topologies are required to analyze the system for

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fault performance, stability, circuit breaker response, and the design of paralleling controls. The enclosed effort requires the development and integration of component-level models into an existing AC zonal distribution package. Specifically, the existing package will be reviewed for syntax and interconnection format. Models for the diesel generators, delta-delta 3-phase transformers, synchronous machines, and associated controls will be formulated. Interconnection requirements will be documented.

**SUMMARY:** A literature search was conducted regarding diesel engine modeling and several strategies were investigated. Modeling equations for the delta-delta transformers and conventional three-phase synchronous machines were formulated. An interconnection strategy was developed based on Mayer's approach of root and non-root models. Control development software was written to aid in the tuning of exciter parameters. Woodward control diagrams were consulted for current topologies. Software implementation was hampered by UNIX system incompatibilities and system administrator delays. Work continues on delivering operational models.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles – Ships and Watercraft

**KEYWORDS:** AC Zonal Distribution, Diesel Generators, Transformers, ACSL Simulation

### DETAILED FAULT CHARACTERIZATION FOR SHIPBOARD POWER SYSTEMS

**John G. Ciezki, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center - Carderock Division**

**OBJECTIVE:** The performance of Navy shipboard power systems during casualty situations is critical in assessing survivability and in formulating improved condition monitoring hardware and control algorithms. Power system damage inflicted by mines, air-to-surface missiles, and other projectiles is manifested in various types of cable short circuits and open circuits. The damage can appear intermittently and it can cascade if monitoring systems are not able to isolate fault locations quickly. The purpose of this work is to develop computer representations of various fault scenarios and match the models to acquired test facility data. This effort entails modeling the test facility generator, developing circuit equations to represent line-line and various fault conditions, including both low impedance and high impedance faults, and modifying the fault impedance representation in a time-varying fashion in order to match the collected data.

**SUMMARY:** A literature review was conducted on techniques used for characterizing time-varying fault impedances. Parameters for the synchronous machine test facility were calculated via test data information. Equations were developed modeling single-phase, phase-to-phase, and three-phase faults for a conventional three-phase machine. Studies were devised for contrasting the ACSL simulations with available KEMA test data. Simulations results have been delayed due to the inability of UNIX administrators to install and get the ACSL software running. Work continues on providing useful deliverables.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles – Ships and Watercraft

**KEYWORDS:** Fault Analysis, AC Generators, ACSL Simulation

### SYMBOLIC MATHEMATICS FOR ON LINE TESTING

**Roberto Cristi, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Unfunded**

**OBJECTIVE:** The purpose of this research is to develop tools for on line testing techniques which are not multiple choice. This will benefit courses in the Applied Sciences areas (Engineering, Mathematics, Physics), where the answers of the students are formulated in terms of mathematical symbols.

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**SUMMARY:** The use of symbolic evaluation software, such as Mathematica, provides the necessary engine for evaluating and assessing the student's responses. The outcomes of this research are presented in J. Biggs' master's thesis and a Website (<http://pclearn.ece.nps.navy.mil>) of a Digital Signal Processing Course (EC2400, currently in the NPS catalog) has been developed. In J. Biggs' thesis, a general architecture for on-line course development is presented. In particular it is shown that by a combination of a number of software tools (JSP, Servlets, Mathematica, WebMathematica and Access), an on-line course can be developed which is capable not only of evaluating student's answers entered in symbolic form, but also of tracking the student's performance in the course. The latter is achieved by a dynamic test, which adapts the questions in the exams to the student's performance. According to this scheme, the student is evaluated on the basis of a number of trials necessary to answer a number of similar questions. In this way the evaluation is not binary (just right or wrong) and it rules out the possibility of guessing. The software developed is also capable of delivering coursework material, keep track of student enrollment, and appropriately schedule tests for the students.

**THESIS DIRECTED:**

Briggs, J., "Web Testing Tools for Electrical Engineering Courses," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel and Training

**KEYWORDS:** On-line Course, Digital Signal Processing

**FEATURE EXTRACTION FOR SIGNAL CHARACTERIZATION IN CLASSIFICATION**

**APPLICATIONS: APPLICATIONS TO COMMUNICATION MODULATION**

**Monique P. Fargues, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Center for Reconnaissance Research**

**OBJECTIVE:** This study completed an on-going research effort investigating various feature extraction schemes and applications to the classification of digital signal modulation types.

**SUMMARY:** The study conducted during FY01 concluded an on-going research effort investigating feature extraction schemes and applications to the classification of digital modulation schemes. The study was split into two phases.

First, a hierarchical tree-based classification approach was considered to the classification of digital modulation schemes of types [2,4,8]-PSK, [2,4,8]-FSK and [16,64,256]-QAM in low SNR levels and multipath propagation channel conditions, where back-propagation neural network units were adopted at each tree node. Higher-order statistics-based class features were investigated and a small number of cumulants and moments chosen to differentiate between all various types of modulation types, except for specific M-QAM types. While being part of the hierarchical procedure, the identification of specific M-QAM types was conducted via equalization algorithms. Extensive simulations show overall classification performances to be strongly affected by the amount of multipath distortion and noise in the transmission channels.

The second phase of the study investigated three discriminant-based feature dimension reduction schemes: the Mean Separator Neural Network (MSNN), the Mahalanobis-based Dimension Reduction scheme (MBDR), and the kernel-based Generalized Discriminant Analysis (GDA) approach. PCA was also included for comparison purposes. All four feature dimension reduction schemes were implemented and evaluated by applying the transformed features to a basic minimum distance classifier. Three classification datasets commonly used in statistics for benchmarking purposes were selected for benchmarking purposes. Results showed the kernel-based generalized discriminant analysis approach to lead to consistently higher classification performances than the other schemes considered in the study for the data investigated.

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### **PUBLICATIONS:**

Fargues, M.P. and Hatzichristos, G., "A Hierarchical Approach to the Classification of Digital Modulation Types in Multipath Environments," *Proceedings of the 35<sup>th</sup> Asilomar Conference on Signals, Signals, and Computers*, November 2001.

Fargues, M.P., *Investigation of Feature Dimension Reduction Schemes for Classification Applications*, Naval Postgraduate School Technical Report, NPS-EC-01-005, June 2001.

Fargues, M.P. and Hatzichristos, G., *A Hierarchical Approach to the Classification of Digital Modulation Types in Multipath Environments*, Naval Postgraduate School Technical Report, No. NPS-EC-01-004, May 2001.

### **THESIS DIRECTED:**

Hatzichristos, G., "Classification of Digital Modulations in Multipath Environments," Masters Thesis, Naval Postgraduate School, March 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Computing and Software

**KEYWORDS:** Classification, Higher-Order Statistics, Kernel Method

### **DETECTION, CLASSIFICATION AND PROCESSING OF WIRELESS LOCAL AREA NETWORK SIGNALS**

**Tri T. Ha, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Information Warfare Activity**

**OBJECTIVE:** Develop a prototype using commercially available low cost hardware and software solutions to detect, classify and process a wireless IEEE 802.11b DSS compliant network signal.

**SUMMARY:** There were routine interactions (through phone conversations, email, meetings, etc.) with the staff, students, government agency and contractor personnel involved in this NIWA sponsored project. This research focuses on developing a prototype system that will allow the detection and process WLAN signals in real time. The prototype system was developed using commercial software and hardware components that can be upgraded and enhanced as the industry standard changes. The research includes the methodology used in selecting the commercial software and hardware components. In addition substantial testing results are included that outline the conditions under which the prototype will be able to receive and process 802.11b WLAN signals. The measured data is compared to radio frequency propagation models, and a simple formula to determine if a signal can be detected is presented. The research concludes with recommendations on how to successfully employ the system in an operational environment.

**DoD KEY TECHNOLOGY AREAS:** Other (Information Operations, Electrical Engineering)

**KEYWORDS:** WLAN, Propagation Model, Wireless

### **NSA/ATD CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT**

**Tri T. Ha, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Security Agency**

**OBJECTIVE:** Support for the Cryptologic Research Lab at the Naval Postgraduate School wherein graduate students perform research in support of ATD (formerly K51).

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**SUMMARY:** The Cryptologic Research Laboratory, sponsored by the National Security Agency's ATD, is a valuable resource which provides a cost effective, viable and robust research platform for NPS graduate students and faculty in Electrical Engineering, Information Warfare, and Computer Science and related curricula. It offers an unclassified environment wherein graduate students can develop an in-depth understanding of cryptology and related disciplines by researching capabilities, limitations, design, and operations of digital signal processing and exploitation techniques, satellite communications technologies, cellular technologies, wireless communications and other analogous cryptologic areas.

### **THESES DIRECTED:**

Halloran, S.P., "Vulnerability Assessment Through Predictive Modeling of IEEE 802.11 Standard Wireless Local Area Networks," Masters Thesis, Naval Postgraduate School, June 2000.

Myers, W.S., "Exploitation of an IEEE 802.11 Standard Wireless Local Area Network Through the Medium Access Control (MAC) Layer," Masters Thesis, Naval Postgraduate School, June 2000.

Oubre, D.I., "Capabilities and Limitations of Orthogonal Frequency-Division Multiplexing in Wireless Applications," Masters Thesis, Naval Postgraduate School, September 2000.

Harrell, A.T., "Wireless Technology Via Satellite Communications for Peacekeeping Operations," Masters Thesis, Naval Postgraduate School, September 2000.

Yokoyama, M.K., "Airborne Exploitation of an IEEE802.11b Wireless Local Area Network," Masters Thesis, Naval Postgraduate School, September 2000.

Count, P.A., "Performance Analysis of OFDM in Frequency Selective, Slowly Fading Nakagami Channels," Masters Thesis, Naval Postgraduate School, December 2000.

**DoD KEY TECHNOLOGY AREAS:** Other (Information Operations, Electrical Engineering)

**KEYWORDS:** Cryptology, Exploitation, Wireless

### **IMPROVEMENT OF THE SIGNAL-TO-NOISE RATIO USING WAVELET RELATED SIGNAL PROCESSING**

**Ralph D. Hippenstiel, Associate Professor  
Department of Electrical and Computer Engineering  
Sponsor: Center for Reconnaissance Research**

**OBJECTIVE:** Investigate wavelet related processing and scale/time tiling to improve the effective SNR of signatures of interest.

**SUMMARY:** The work investigates the improvement of the estimate of signals which are embedded in white Gaussian noise. The first part evaluates the use of a wavelet based decomposition to denoise signals. The denoising is achieved in the wavelet domain using i) median and ii) predictive filtering. The second part focuses on the use of Fourier transform based denoising, where the denoising is applied in the time-frequency domain. The denoising uses median or predictive filtering. Improvement is measured using the mean square error.

### **THESES DIRECTED:**

Hughes, J., "Signal Enhancement Using Time-Frequency Based Denoising," Masters Thesis, Naval Postgraduate School, in progress.

Kan, H.E., "Signal Enhancement," Masters Thesis, Naval Postgraduate School, in progress.



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**DoD KEY TECHNOLOGY AREA:** Electronics

**KEYWORDS:** Signal Enhancement, Signal Classification, Wavelet Based Decomposition, Denoising, Time-Frequency Based Filtering

### DEFENSE TECHNOLOGY AND SYSTEMS COURSE

**David C. Jenn, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsors: National University of Singapore**

**OBJECTIVE:** Generate and deliver a comprehensive set of lectures that cover the topics of basic electromagnetics, transmission lines, antennas, propagation, scattering, radar, jamming, and sensor integration and fusion. Design a set of computer based laboratory exercises based on the lecture material. The total length of the course is four days and two exams are given to evaluate student performance.

**SUMMARY:** Lecture notes were based on the material in NPS courses EO2652, EO3602 and EO4612. The notes were initially generated for last year's course, but significant modifications were required for this year's course. The course also uses a set of Matlab based computer exercises for instruction in each of the topic areas.

**PUBLICATIONS:** "Sensors," 13 volume set of lecture notes (352 pages) in PDF format.

**PRESENTATIONS:** DTSC lectures and laboratory supervision (4 days).

**DoD KEY TECHNOLOGY AREA:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Antennas, Electromagnetics, Sensors

### EFFECTIVENESS OF BROADBAND ANTENNA DESIGNS

**David C. Jenn, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: QRC, Inc.**

**OBJECTIVE:** Several broadband antenna designs were evaluated for use in a ground penetrating radar for buried ordinance detection.

**SUMMARY:** A combination of measurement, analysis, and simulation was used to evaluate several antennas for use in a ground penetrating radar for the detecting buried ordinance (mines and unexploded bombs). Candidate antennas included the contra-wound helix, contra-wound log-periodic spiral and a sinuous cavity backed slot. A method-of-moments computer code was used to evaluate the antenna input impedance and near field patterns.

#### **PUBLICATION:**

Jenn, D.C. and Wollny, W.T., "Broadband Focused Radar at Ground Penetrating Frequencies for Detecting Mines," Final Report submitted to Army Research Office, Mechanical and Environmental Sciences Division, Engineering Sciences Directorate, November 2001.

#### **PRESENTATION:**

Jenn, D.C. and Wollny, W.T., "Broadband Antenna Study for Buried Object Detection," Army Research Office, Ft. Belvoir, 12 October 2001.

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**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Antennas, Electromagnetics, Sensors

### HELICOPTER PAYLOAD PHASE 1 ANTENNA STUDY

**David C. Jenn, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Command**

**OBJECTIVE:** The objective of this study was to determine the optimum antenna placement given the available locations on the helicopter. The suitability of a location is determined by the quality of the antenna pattern, primarily field-of-view, which is defined as the range of angles over which the antenna gain is constant enough and/or sufficient enough to permit signal reception regardless of the direction of flight.

**SUMMARY:** An analysis and simulation of the antenna installed on the helicopter was conducted using computational electromagnetics (CEM) codes. The simulated pattern data for the installed antenna was compared to that of the free standing antenna, which is used as a baseline from which to determine the effects of the antenna placement on signal reception. If the installed antenna pattern deviates significantly from the baseline antenna pattern, then the reception is potentially degraded. The frequency range of interest was 100 MHz to 1200 MHz.

#### **PUBLICATION:**

Jenn, D.C., *Helicopter Payload Phase 1 Antenna Study*, Naval Postgraduate School Technical Report, NPS-EC-01-008, October 2001.

#### **PRESENTATION:**

Jenn, D.C., "VTUAV Phase 1 Antenna Study Results," VTUAV Program Review, Northrop-Grumman-Ryan Aerospace, San Diego, CA, 21 June 2001.

**DoD KEY TECHNOLOGY AREA:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Antennas, Electromagnetics, Sensors

### DAR REMOTE SENSING

**Jeffrey B. Knorr, Professor**

**Department of Electrical and Computer Engineering**

**Bob Bluth, Research Associate**

**Center for Remotely Piloted Aircraft Studies**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** The objective of this project is to acquire and modify two military radars for meteorological research.

**SUMMARY:** An Army AN/MPQ-64 Sentinel radar was acquired in the Spring of 1999 and was brought to operational status during the Fall of 1999 and the Winter of 2000. An SBIR project, N01-035, Weather Processor for Rapid Scanning Tactical Radars, was initiated with ProSensing, Amherst, MA to add a Doppler processor to the radar for severe storm research. During May 2001, a meeting was held with ProSensing engineers to discuss details associated with the addition of the weather processor. It is expected that initial testing of the processor will take place during 2002.

During 2000 steps were also taken to obtain an Army AN/TPQ-37 Firefinder radar. A radar was delivered in the Spring of 2001 but the Army subsequently requested that the radar be returned to satisfy

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another requirement and it was relinquished in the Fall of 2001. The AN/TPQ-37 radar is similar to the AN/SPY-1 radar installed on the Navy's Aegis cruisers and destroyers. A project was planned to add a weather processor to this radar so it could be used as a testbed for investigation of AN/SPY-1 algorithms to extract meteorological data. This goal must now await the acquisition of another AN/TPQ-37 radar.

The overall long term objective of this project is to develop radar remote sensing capabilities that will provide meteorological data that can be used to describe weather phenomena, particularly in support of air operations in the fleet battlespace.

### **PRESENTATION:**

Knorr, J.B., Bluth, R. and Pazmany, A., "Rapid Scan 3D Volumetric Weather Radar," 30<sup>th</sup> International Conference on Radar Meteorology, Munich, Germany, 14-19 July 2001.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Sensors

**KEYWORDS:** Remote Sensing, Radar Meteorology

### **ANTENNA DEVELOPMENT FOR MAN-PACK TACTICAL RADIOS**

**Jovan Lebaric, Visiting Associate Professor**

**Richard Adler, Research Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: U.S. Army Soldier Biological Chemical Command**

**OBJECTIVE:** The objective is to improve the design a conformal, wearable RF vest antenna for low VHF, and to design a compact antenna for a hand-held field radio operating in the 30 to 88 MHz band.

**SUMMARY:** The research, development and design will be accomplished by optimizing the antenna and feed region shape, adding commercially available cladding material in the feed region, and integrating the RF vest with the Kevlar flak vest. The feed region cladding and shaping will reduce the near-field coupling to the operator and increase the antenna efficiency. The compact antenna design will be directed towards using dielectric and resistive loading to reduce the antenna VSWR while maintaining antenna radiation efficiency as high as possible.

### **PUBLICATION:**

Lebaric, J., Adler, R.W. and Limbert, M., "Ultrawideband, Zero Visual Signature RF Vest Antenna for Man-Portable Radios," MILCOM 2001, McLean, VA, 28-31 October 2001.

### **PRESENTATION:**

Lebaric, J., Adler, R.W. and Limbert, M., "Ultrawideband, Zero Visual Signature RF Vest Antenna for Man-Portable Radios," MILCOM 2001, McLean, VA, October 2001.

### **OTHER:**

The NPS IP counsel has been informed that patent for "The Wearable Ultrawideband Vest Antenna" will be issued by the USPTO within a couple of months.

### **THESIS DIRECTED:**

Limbert, M., "Ultrawideband Combat Wearable Integrated (COMWIN) Antenna Design for the Joint Tactical Radio System (JTRS)," Masters Thesis, Naval Postgraduate School, September 2001.

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**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Communications, Antennas

### **DESIGN AND PROTOTYPING OF WIDEBAND USQ-113 ANTENNA FOR EA-6B**

**Jovan Lebaric, Visiting Associate Professor**

**Richard Adler, Research Associate Professor**

**Andrew Parker, Research Associate**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Air Systems Command**

**OBJECTIVE:** Design and prototype an ultrawideband antenna for the USQ-113 system onboard EA-6B aircraft, such as to meet the specifications, especially height imposed by the operational aircraft use (carrier landing and take-off).

**SUMMARY:** This design is an evolution of the “bell” antenna design tested at NPS in FY99. The new design has a reduced height and weight, a modified shape, and addition of new elements. The design is a compromise between the optimal electrical performance for a given height constraint and the aerodynamic constraint of the high-speed platform the antenna is intended for.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Information Warfare, Jamming, Antennas

### **HELMET MOUNTED UHF ANTENNA FOR SATELLITE COMMUNICATIONS**

**Jovan Lebaric, Visiting Associate Professor**

**Richard Adler, Research Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Command**

**OBJECTIVE:** The objective is to design a satellite communications antenna for integration with a standard-issue U.S. military helmet, within DoD Instruction 605.11 defined parameters.

**SUMMARY:** The objective will be accomplished using a conformal two-arm spiral antenna design for circular polarization. The spiral will be embedded in a protective layer that would also increase the electrical length of the antenna. A shorted ring will be added at the bottom of the conformal two-arm spiral to improve the front-to-back ratio and reduce the operator near-field exposure below the levels specified in the DoD 605.11 standard.

#### **THESIS DIRECTED:**

Gibbs, D., “Design of Mobile User Objective System (MOUS) Helmet Mounted UHF Antenna,” Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Satellite Communications, Antennas

## PROJECT SUMMARIES

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### **USQ-146 LOW-PROFILE OMNI-DIRECTIONAL ULTRA-WIDEBAND ANTENNA FOR SHIPBOARD AND VEHICULAR USE**

**Jovan Lebaric, Visiting Associate Professor**  
**Richard Adler, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Information Warfare Activity**

**OBJECTIVE:** The objective is to design a low-profile omni-directional ultrawideband antenna for the USQ-146 system. The antenna will be installed on land-based vehicles or onboard ships.

**SUMMARY:** The antenna design is based on the mono-conical antenna with matched loading to reduce the antenna VSWR at the low end, with minimum reduction in antenna efficiency throughout the operating frequency range. Also, the design allows for increasing the antenna height using elements stowed inside the cone and deployed “on-demand.”

**THESIS DIRECTED:**

Koutras, N., “Ultra-Wideband Antenna Designs for Military Vehicle Applications,” Masters Thesis, Naval Postgraduate School, March 2001.

**OTHER:** Patent application submitted to NPS IP Counsel.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Information Warfare, Jamming, Antennas

### **USQ-146 LOW-PROFILE QUADRANT-SWITCHABLE-BEAM ULTRA-WIDEBAND ANTENNA FOR SHIPBOARD AND VEHICULAR USE**

**Jovan Lebaric, Visiting Associate Professor**  
**Richard Adler, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Information Warfare Activity**

**OBJECTIVE:** The objective is to design a low-profile ultra-wideband transmit antenna with steerable beams for the USQ-146 Rubicon system. The antenna would be used in a shipboard environment or land-based vehicle.

**SUMMARY:** The design objectives will be accomplished by employing a mono-cone and bi-cone designs with special loading such that directional properties are obtained. Mechanical rotation of the loading element provides for beam steering. The directivity is a function of frequency, above 10 dB from most of the operating range. The loading material can have a loss component added for the “out-of-band” RCS reduction.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Information Warfare, Jamming, Antennas

## PROJECT SUMMARIES

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### ULTRA-WIDEBAND ANTENNA FOR THE USQ-146 INSTALLATION IN THE H-60 HELICOPTER

Jovan Lebaric, Visiting Associate Professor

Richard Adler, Research Associate Professor

Andrew Parker, Research Associate

Department of Electrical and Computer Engineering

Sponsor: Naval Information Warfare Activity

**OBJECTIVE:** The objective is to design, fabricate and test an ultra-wideband transmit antenna for the USQ-146 installation in the H-60 helicopter.

**SUMMARY:** The platform operational restrictions on landing and take-off restrict the design to a height of only 10 inches while the operational requirements call for an ultrawideband antenna capable of efficient operation at low frequencies where the permissible antenna height becomes a very small fraction of the operating wavelength. Several approaches have been investigated. One approach led to an antenna design such that the antenna is mechanically rotated into the operating position from a stowed position that satisfies the height constraint. Another design is currently under development for an ultrawideband antenna with no moving parts.

**THESIS DIRECTED:**

Adams, J., "Ultrawideband Antenna Design for the USQ-146 Installation for the H-60 Helicopter," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Information Warfare, Jamming, Antennas

### DESIGN OF A CLASSIFIED COMMUNICATIONS SATELLITE SYSTEM

Herschel H. Loomis, Jr., Professor

Department of Electrical and Computer Engineering and Space Systems Academic Group

Sponsor: Hughes Space and Communications

**OBJECTIVE:** To provide technical support to a design effort for a government communications satellite system.

**SUMMARY:** Provided technical support to the design of the communications waveform design and concept of operations of a classified communications satellite system for the U. S. government.

**DoD KEY TECHNOLOGY AREAS:** Other (Information Superiority)

**KEYWORDS:** Communications Satellite, Communications Waveform Design

### NSA/C4 COMPUTER NETWORK RESEARCH LABORATORY AND THESIS RESEARCH

Herschel H. Loomis, Jr., Professor

Department of Electrical and Computer Engineering and Space Systems Academic Group

CAPT James Powell, USN

Department of Information Science

Sponsor: National Security Agency

**OBJECTIVE:** This effort will continue and expand and enhance the capabilities and research focus of the computer network research laboratory.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Computing and Software

**KEYWORDS:** Network, Security, Computer, Software, Information Operations

### NAVAL SIMULATION SYSTEMS CRYPTOLOGIC STUDIES

**Hershel H. Loomis, Jr., Professor**

**Department of Electrical and Computer Engineering and Space Systems Academic Group**

**Sponsor: Space and Naval Warfare Systems Center - San Diego**

**OBJECTIVE:** NPS will provide a tailored technical update to the 04/05 mid-career CNSG course to meet schedule and educational requirements.

**SUMMARY:** The course was taught at CNSG headquarters (HQ) from 5-9 February 2001. The course will cover technical aspects of signals intelligence (SIGINT) to include an understanding of SIGINT concepts, information assurance and information operations. The course addressed difficult technical concepts as themes. Each theme provides the cryptologist the essence of the area of study. Three basic themes were selected to focus and organize the topics of instruction.

**DoD KEY TECHNOLOGY AREAS:** Other (Information Superiority)

**KEYWORDS:** Signals Intelligence

### PROJECT GUSTY ORIOLE

**Hershel H. Loomis, Jr., Professor**

**Department of Electrical and Computer Engineering and Space Systems Academic Group**

**RADM Thomas C. Betterton, USN (Ret), Naval Space Technology Chair**

**Alan Ross, Navy Tactical Exploration of National Capabilities (TENCAP) Chair Professor**

**Space Systems Academic Group**

**Sponsor: Secretary of the Air Force**

**OBJECTIVE:** To conduct research into architectures and algorithms for the acquisition, processing, and communication of tactical information. To provide support for the course Space Systems 3001, Military Applications of Space and SS4051, Military Space Systems and Technologies.

**SUMMARY:** Completed work on the following tasks: a) Developed plans for a Satellite Communications System, which has been funded through Boeing Space Systems. b) Triple-modular-redundancy computer designs completed for 64-bit microprocessor and for DSP COTS ASIC. Continued service on Ph.D. committee for NRL code 8000 employee on modeling of behavior of microprocessors in Single Event Effect environment. c) Began book *Emitter Geolocation* in collaboration with Dr. Michael Price. d) Supported Courses SS 3001 & SS4051 by the development of geolocation material and the arrangement of field trips to visit contractor sites. e) Attended meetings of government LPI Communications Committee; hosted 2-day meeting of committee at NPS in January 2001.

### PUBLICATIONS:

Miller, J.B., McEachen, J.C., Loomis, H.H., Tope, M.A. and Copeland, D.B., "An Analysis of Noise in Timing-based Communications over LANs," accepted by ISCAS 2002, the IEEE International Symposium on Circuits and Systems.

Loomis, H.H., *Geolocation of Electromagnetic Emitters*, Naval Postgraduate School Technical Report, NPS-EC-00-003, January 2001 (revised edition).

## PROJECT SUMMARIES

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### THESES DIRECTED:

Ecken, H.B., "Feasibility Analysis and Design of a Fault Tolerant Computing System: A TMR Microprocessor System Design of 64-Bit COTS Microprocessors," Masters Thesis, Naval Postgraduate School, March 2001.

Wukich, M.J., "Using Commercial Off The Shelf (COTS) Digital Signal Processors (DSP) for Reliable Space Based Digital Signal Processing," Masters Thesis, Naval Postgraduate School, March 2001.

Johnson, J.J., "Implementing the Cross Ambiguity Function and Generating Geometry-Specific Signals," Masters Thesis, Naval Postgraduate School, September 2001.

Dorcey, C.T., "FFT-Based Spectrum Analysis Using a Digital Signal Processor," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles, Sensors

**KEYWORDS:** Space-based Reconnaissance, Signals Intelligence

### SECURITY VULNERABILITIES OF WIRELESS PROTOCOLS

**John McEachen, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Engineering Logistics Office**

**OBJECTIVE:** Perform research into the internal protocols of wireless computer networks and identify vulnerabilities associated with their standard implementation. Examine use of cellular-based protocols such as Mobitex and CDPD for data communications. Begin investigation into the interface of wireless networks with landline IP networks in the interest of examining upcoming technologies such as WAP and IP telephony.

**SUMMARY:** Interest in portable, high-bandwidth digital communications methods spans the world and presents a formidable challenge to the Defense Department of the United States. While anxious to use new communications equipment, the armed services are wary of the vulnerabilities they expose. This project examines the vulnerability of wireless local area networks (WLANs) when used by tactical units in an urban setting. Initial efforts on this project consisted of the development of a baseline IEEE 802.11a computer simulation using OPNET. These models have been highly praised and are already in use by organizations such as Philips Electronics and BDM. More recent efforts have focused on the stand-off detection ranges of WLANs. This project also has identified several denial of service issues in the IEEE 802.11 control and management functions.

### PUBLICATIONS:

McEachen, J.C. and Cay, A., "Queue Response of Correlated Traffic Insertion in ATM Networks," *IEEE Transactions in Networking*, in review.

McEachen, J.C. and Cay, A., "Connection Utilization Masking in ATM Networks," *International Journal on Information Security*, in review.

Tope, M.A. and McEachen, J.C., "Unconditionally Secure Communications over Fading Channels," *Proceedings of the 2001 IEEE Military Communications International Symposium (MILCOM 2001)*, Washington, D.C., October 2001.

Mullin, S.C. and McEachen, J.C., "Vulnerabilities in Multiprotocol Label Switching Label Distribution," *Proceedings of the 2001 IEEE Military Communications International Symposium (MILCOM 2001)*, Washington, D.C., October 2001 (classified publication).



## PROJECT SUMMARIES

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Braswell, B.E. and McEachen, J.C., "Modeling Data Rate Agility in the IEEE 802.11a WLAN Protocol," *Proceedings of OPNETWORK2001*, Washington, D.C., August 2001.

Braswell, B.E., McEachen, J.C. and Batson, M.S., "A Baseline Model for IEEE 802.11a WLAN Protocol," *Proceedings of OPNETWORK2001*, Washington, D.C., August 2001.

McEachen, J.C. and Cay, A., "Masking Compressed Video Connection Utilization in ATM Networks," *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Vol. V, Sydney, Australia, pp. 145-148, May 2001.

McEachen, J.C., Ow, K.C. and Lim C.T., "A System Level Description and Model of Signaling System No. 7," *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Vol. IV, Sydney, Australia, pp. 258-261, May 2001.

McEachen, J.C., *Route Intervention in Packet Networks*, Naval Postgraduate School Technical Report, NPS-EC-01-009, May 2001 (Classified Top Secret/SCI).

McEachen, J.C. and Braswell, B., *Vulnerabilities in Control and Management Functions of IEEE 802.11 Wireless LANs*, Naval Postgraduate School Technical Report, NPS-EC-01-001, February 2001.

### PRESENTATIONS:

McEachen, J.C., "Computer Networking in the Department of Defense," lecture to Introductory Engineering Class, Santa Clara University, 8 November 2001.

McEachen, J.C., "Teaching with OPNET," OPNETWORK2001, Washington, D.C., 30 August 2001.

### THESES DIRECTED:

Mallory, P.L., "Extending IEEE 802.11b Wireless Local Area Networks to the Metropolitan Area," Masters Thesis, Naval Postgraduate School, December 2001.

Geissler, W.K., "Exploitation of Transmission Control Protocol Error Handling as a Means of Covert Communications," Masters Thesis, Naval Postgraduate School, September 2001.

Maloy, R.C., "Performance Metrics for an ATM Network Using Local Area Network Emulation (LANE) and Switched Ethernet," Masters Thesis, Naval Postgraduate School, September 2001.

Kinney, A.C., "Analysis of M-JPEG Video over an ATM Network," Masters Thesis, Naval Postgraduate School, June 2001.

Braswell, B.E., "Modeling Data Rate Agility in the IEEE 802.11a Wireless Local Area Networking Protocol," Masters Thesis, Naval Postgraduate School, March 2001.

Mullin, S.C., "Vulnerabilities of Multiprotocol Label Switching," Masters Thesis, Naval Postgraduate School, March 2001.

Tan, K.C., "Development and Simulation of the IEEE 802.11a Physical Layer in a Multipath Environment," Masters Thesis, Naval Postgraduate School, March 2001.

Chua, G.H., "An Architecture for Analysis and Collection of RF Signals Used by Hand-held Devices in Computer Communications," Masters Thesis, Naval Postgraduate School, March 2001.

Lam, W., "Meeting SIGINT Constraints in IP Telephony," Masters Thesis, Naval Postgraduate School, March 2001.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications, Modeling and Simulation, Computing and Software

**KEYWORDS:** 802.11, ATM, Wireless, LAN, High Speed Networking, Ad-Hoc Networking

### THERMODYNAMIC MODELING FOR INTRUSION DETECTION

**John McEachen, Assistant Professor**

**Department of Electrical and Computer Engineering**

**James Luscombe, Professor**

**Department of Physics**

**Chris Frenzen, Associate Professor**

**Department of Applied Mathematics**

**Sponsor: Defense Information Systems Agency**

**OBJECTIVE:** Develop alternative methods for intrusion detection in computer networks. Specifically, examine the use of statistical mechanics in modeling the dynamics of network conversations.

**SUMMARY:** This interdisciplinary project explored the use of thermodynamic principles to model the flux of conversations across a network boundary. The major deliverable of this project was the Terminator 2 software program developed and installed at the U.S. Pacific Command. A revised version of the software was also installed at the U.S. Army Signal Command, Ft. Huachuca, AZ.

### PUBLICATIONS:

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K., "Using Thermodynamics to Model Network Conversation Dynamics for Intrusion Detection," *IEEE Transactions in Networking*, in review.

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K., "A Thermodynamics-based Model of Network Conversation Flux for Intrusion Detection," to appear in *Proceedings of the IIIS 6th World Multi Conference on Systemics, Cybernetics and Informatics (SCI 2002)*, Orlando, FL, July 2002.

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K., "Therminator 2: A Thermodynamics-based Method for Patternless Intrusion Detection," to appear in *Proceedings of the 2002 IEEE Military Communications International Symposium (MILCOM 2000)*, Los Angeles, CA, October 2002.

### PRESENTATIONS:

McEachen, J.C., "Therminator 2: A Real Time Thermodynamic-Based Patternless Intrusion Detection System," AFWIC Phoenix Challenge 2002, Las Cruces, NM, 20 February 2002.

### THESES DIRECTED:

Donald, S.D. and McMillen, R.V., "Therminator 2: Developing a Real Time Thermodynamic Based Patternless Intrusion Detection System," Masters Thesis, Naval Postgraduate School, September 2001.

Sharlun, G.F., "Defining and Validating a Covert Analysis Detection (CAD) System and its Stealthy Data Capture, Control and Analysis Capabilities," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications, Modeling and Simulation, Computing and Software

**KEYWORDS:** Intrusion Detection, Thermodynamics, Statistical Mechanics, High Speed Networking

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## PROJECT SUMMARIES

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### **TIMING CHANNELS IN PACKET NETWORKS**

**John McEachen, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Security Agency**

**OBJECTIVE:** Examine the use of packet timing as an alternative communications mechanism. Characterize delay in a variety of network environments.

**SUMMARY:** This project is based on the work of B. Verdu (1998) in communicating information using inter-packet delay in data networks. This work is largely classified. Work on this project began in February 2002.

#### **PUBLICATIONS:**

Miller, B., Copeland, D., Tope, M., Loomis, H. and McEachen, J.C., "An Analysis of Noise in Timing-based Communications over LANs," to appear in *2002 IEEE International Symposium on Circuits and Systems*, Phoenix, AZ, May 2002.

**DoD KEY TECHNOLOGY AREA:** Command, Control and Communications

**KEYWORDS:** Packet Networks, Information Theory, Steganography

### **RADIATION TOLERANT ASIC AND PHOTOVOLTAIC DEVICES FOR SPACE BASED SYSTEMS**

**Sherif Michael, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** To design radiation tolerant mixed mode VLSI and ASIC circuits for space applications. To fabricate these design after extensive simulation using regular silicon process as a first step. To study the Space radiation effects on these state-of-the-art designs using the NPS LINAC as a radiation source. Upon verification of the experimental results, the layout will be submitted for future fabrication using SOI process.

**SUMMARY:** Continuation of the ongoing research on radiation effects and the design of radiation hardened electronic devices for space applications. The design and fabrication of a high performance digitally programmable VLSI circuit for space-based system. The design is based on a technique that was developed earlier by the investigator, and has shown excellent sensitivity performance. The mixed mode signal circuit, using BiCMOS Techniques is currently under development. Previously fabricated VLSI ASIC chips will also be irradiated using the NPS LINAC for testing its performance under radiation environment. Past experimental results using this technique has shown great improvements in the circuits radiation performance.

#### **PUBLICATIONS:**

Michael, S. and Pieper, R., "A VLSI Implementation of a Universal Programmable Low Sensitivity Sampled Data Filter," *IEEE International Symposium on Circuits and Systems*, Vol. 4, pp. 674-677. Sydney, Australia, 6-9 May 2001.

Pieper, R. and Michael, S., "Application of a Robust Algorithm for Predicting Freeze-out and Exhaustion Under a Variety of Nontrivial Conditions," *IEEE International Symposium on Circuits and Systems*, Vol. 2, pp. 477-480, Sydney, Australia, 6-9 May 2001.

## PROJECT SUMMARIES

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### THESES DIRECTED:

Fifer, T., "Radiation Effects on Multi-Junction Solar Cells," Masters Thesis, Naval Postgraduate School, December 2001.

Milne, P.R., "The Design, Simulation, and Fabrication of a BiCMOS VLSI Digitally Programmable Filter," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Environmental Effects, Other (Space Applications)

**KEYWORDS:** Space Radiation Effects, Satellites, Annealing, Radiation Hardened, Computer Modeling

**GUSTY YEARLING, TASK A**  
**Michael A. Morgan, Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Engineering Logistics Office**

**OBJECTIVE:** This is a TS level compartmented Special Access Project. No accurate description can be provided for publication in this forum.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Antennas, Propagation, Impulse Radiation

**MAGNETIC FIELD SENSOR PLACEMENT  
AND TIME-REVERSED EM IMAGING STUDIES**  
**Michael A. Morgan, Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Office of Naval Research**

**OBJECTIVES:** This project included two independent investigations, each of which formed the topic of an M.S. Thesis. The first topic sought to optimize near-surface sensor placements to increase the prediction accuracy of magnetostatic near-fields surrounding ferromagnetic objects. Time-reversed wave equation solutions in acoustics were extended to electromagnetics in the second topic, with application to radar imaging.

**SUMMARY:** Progress for the first topic included: (1) development of a modal algorithm for the field solution due to an axial array of dipoles enclosed within a ferromagnetic spheroidal shell; (2) testing with additive noise of an SVD based least-squares field prediction algorithm using point sensor data, and; (3) extensive searches for optimal sensor placement configurations and the cataloging of findings. Progress for the second topic included development of a finite-difference time-domain simulation and evaluation of imaging accuracy for various levels of noise and sparsity of boundary data.

### PRESENTATIONS:

Morgan, M.A. and Steenman, D.G., LT, USN, "Null Spaces for Near-Field Imaging," 2001 URSI National Radio Science Meeting, Boston, MA, 10 July 2001.

Morgan, M.A., Yopp, S.W., LT, USN and Kildishev, A.V., "Optimal Sensor Placement for Magnetic Signature Prediction," 2001 Intermag Symposium, Amsterdam, Netherlands, 2 May 2001.

Kildishev, A.V., Nyenhuis, J.A. and Morgan, M.A., "Multipole Analysis of an Elongated Magnetic Source by a Cylindrical Sensor Array," 2001 InterMag Symposium, Amsterdam, Netherlands, 2 May 2001.

## PROJECT SUMMARIES

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### THESES DIRECTED:

Yopp, S.W., "Magnetic Field Estimation Using Optimal Locations of Near Field Sensors," Masters Thesis, Naval Postgraduate School, June 2001.

Inaba, Y., "Radar Target Imaging Using Time-Reversed Processing," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Optimal Sensor Placement, Magnetostatic Field Prediction, Time-Reversed Electromagnetics, Radar Imaging

### OPTIMIZED WIDEBAND LOW-PROFILE COMMUNICATION ANTENNA DESIGN

**Michael A. Morgan, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: U.S. Army Research Office**

**OBJECTIVE:** Optimal designs of wideband omnidirectional VHF communication antennas will be investigated for rotary-wing and armored vehicle applications.

**SUMMARY:** Optimization will involve tradeoffs of antenna performance and efficiency constrained by required bandwidth and use of blister type profiles for low aerodynamic drag and minimal surface protrusion. Design will use metallic surface contouring and inhomogeneous dielectric loading under size and shape constraints.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Wideband, Finite Elements, Antenna Design

### MODELING AND SIMULATION OF IMPULSIVE RADIATION AND PROPAGATION

**Michael A. Morgan, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center**

**OBJECTIVE:** The goal of this task is to investigate the impulse radiation characteristics of specified antennas in the presence of buildings over real earth

**SUMMARY:** Wire-grid numerical modeling of antenna and building structures has been completed using frequency-stepped calculations using the Numerical Electromagnetics Code (NEC-4). Impulsive near-fields within the modeled building are found using time-domain source modeling and inverse FFT convolution. Animations of fields within the structure are created using custom MatLab programs.

### PRESENTATION:

Morgan, M.A., "Impulsive Field Computation and Measurement," 2001 URSI National Radio Science Meeting, Boston, MA, July 10, 2001.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Impulse Response, Antenna Modeling, Near-Fields, NEC

## PROJECT SUMMARIES

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### DETERMINING AN OPTIMUM SENSOR NETWORK CONFIGURATION

Phillip E. Pace, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Air Systems Command

**OBJECTIVE:** This proposal investigates using the Advanced Reactive Electronic Warfare Simulation (ARES) to determine optimum sensor network configurations for applications in electronic attack (EA) and suppression of enemy air defense (SEAD).

**SUMMARY:** As a first step, appropriate measures of effectiveness (MOEs) were developed in order to define the fitness of a sensor network. For example, a “perfect” sensor network would know everything about the environment with 100% accuracy instantaneously. Appropriate MOEs, therefore, would optimize the sensor network (radars and ESMs) toward perfection (e.g., minimize latency, maximize information content). Working closely with Code 5700 the developed MOEs were embedded into the ARES. The various MOEs were tested to quantify the sensitivity of the solution to (a) the choice of MOE, and (b) the application. From this it was determined if there was an overall best MOE for optimizing the sensor network. The optimized sensor network was applied to several engagement problems (EA and several types of SEAD) in order to determine how well network supported the application.

#### THESIS DIRECTED:

Pham, P.N., “Sensitivity Analysis of an Optimum Multi-Component Airborne Electronic Attack Configuration for Suppression of Enemy Air Defense,” Masters Thesis, Naval Postgraduate School, March 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics, Modeling and Simulation

**KEYWORDS:** Electronic Attack, Network-Centric Warfare, Optimum Sensor Configuration, Measures of Effectiveness

### DIGITAL TARGET IMAGING ARCHITECTURES

Phillip E. Pace, Professor

Douglas J. Fouts, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

**OBJECTIVE:** The technical objective of this research is twofold. The first objective is to quantify the system-level implementation tradeoffs of a digital, programmable imaging architecture to generate realistic false target signatures against high resolution imaging radars, including synthetic aperture radar (SAR) and inverse SAR (ISAR), using all-digital techniques and modern digital radio frequency memory (DRFM) technology. The second objective is to design, fabricate and test an all-digital target imaging device capable of generating large false targets using wideband chirp signals of any duration to provide a new, superior, radio frequency (RF) decoy capability.

**SUMMARY:** A sequence of simulations was completed to quantify various different design tradeoffs in the high-level architecture of the digital image synthesizer (DIS). The simulations were started during the previous year’s effort of this 3-year project. Based on the simulation results, a new, high-performance architecture was developed for the DIS. The design of a high-speed CMOS application-specific integrated circuit (ASIC) that implements the new architecture was then started. The design of this ASIC is now more than half completed, including schematic capture, circuit simulation, mask layout, design rule checking, layout verification, and logic simulation. Simulations indicate the ASIC will function correctly at clock speeds of up to 780 MHz, well beyond the 600 MHz target frequency of the baseband signal. An interface circuit is also being developed to interface the ASIC with a new type of DRFM being developed at the Naval Research Laboratory.

## PROJECT SUMMARIES

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### PUBLICATIONS:

Fouts, D.J., Pace, P.E., Karow, C. and Ekestorm, S., "A Single Chip False Target Radar Image Generator for Countering Wideband Imaging Radars," *IEEE Journal of Solid State Circuits* (accepted for publication).

Pace, P.E., Fouts, D.J., Ekestorm, S. and Karow, C., "Digital False Target Image Synthesizer for Countering ISAR," *IEE Proceedings Radar, Sonar and Navigation* (in review).

### PRESENTATIONS:

Pace, P.E. and Fouts, D.J., "Digital Target Imaging Architecture for Multiple Large-Target Generation," Office of Naval Research Electronic Warfare Science and Technology Gatherings, Washington, D.C., 9 May 2001.

Pace, P.E., Fouts, D.J., Amundson, C.A. and Guillaume, C., "Digital Target Imaging Architecture for Multiple Large-Target Generation: Critical Design Review," Naval Research Laboratory, Washington, D.C., 6 September 2001.

Fouts, D.J. and Pace, P.E., "Digital Target Imaging Architecture for Multiple Large-Target Generation: Progress Report," Office of Naval Research, Washington, D.C., 19 December 2001.

### THESES DIRECTED:

Kirin, K.M., "VLSI Design of Sin/Cos Lookup Table for Use With Digital Image Synthesizer ASIC," Masters Thesis, Naval Postgraduate School, June 2001.

Amundson, C.A., "Design, Implementation, and Testing of a High Performance Summation Adder for Radar Image Synthesis," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics, Computing and Software

**KEYWORDS:** Imaging Decoys, Inverse Synthetic Aperture Radar, Counter-Targeting, Counter-Terminal, Digital Radio Frequency Memories, DRFM

### NAVY SURFACE ANTI-SHIP CRUISE MISSILE THREAT SIMULATOR VALIDATION WORKING GROUP

**Phillip E. Pace, Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Research Laboratory**

**OBJECTIVE:** The objective of this proposal is to provide technical leadership to the Navy Surface Anti-Ship Cruise Missile Threat Simulator Validation Working Group. Three types of simulations are currently being validated by the SVWG for use in test and evaluation. These include (a) radio frequency missile hardware simulators, (b) infrared missile hardware simulators and (c) computer models of missile seekers and related electronics.

**SUMMARY:** The duties for the SVWG chairman include coordinating with the Navy's Simulator Validation Coordinator, the NRL ENEWS Program Manager and other Navy commands (e.g., Commander Operational Test and Evaluation Force) to prioritize the simulator validations for N912 approval. Additional responsibilities include coordinating with the Office of Naval Intelligence for threat data review and convening the SVWG as an independent and unbiased reviewer for all of the validation reports.

## PROJECT SUMMARIES

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### PUBLICATIONS:

Pace, P.E., Zulaica, D., Nash, M.D., DiMattesa, A.D. and Hosmer, A.C., "Relative Targeting Architectures for Captive-Carry HIL Missile Simulator Experiments," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 37, No. 3, pp. 810-823, July 2001.

Pace, P.E., "Adaptive Power-Managed FMCW Emitter Detection Performance Against Low-RCS Ships," *Proceedings of the IEEE 35<sup>th</sup> Asilomar Conference on Signals, Systems and Computers, MP8b*, Monterey, CA, 2 November 2001.

### PRESENTATION:

Pace, P.E., "Infrared Systems and Analysis," N9 Threat ASCM Simulator Validation Working Group, Naval Research Laboratory, 26 June 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics, Computing and Software

**KEYWORDS:** Anti-Ship Cruise Missiles, Simulators, Captive-Carry, Hardware-in-the-Loop

### OPTIMUM SENSOR NETWORK CONFIGURATION FOR SEAD

**Phillip E. Pace, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Johns Hopkins University, Applied Physics Laboratory**

**OBJECTIVE:** This proposal continues the investigation using the Advanced Reactive Electronic Warfare Simulation (ARES) to determine optimum sensor network configurations for applications in electronic attack (EA) and suppression of enemy air defense (SEAD).

**SUMMARY:** A sensitivity analysis of the solution evolved by simulation was performed in order to determine the robustness in the derived measures of effectiveness to system failures or variances in the performance parameters. The tasks involved with this effort included simulating the RT-4 distributed scenarios to baseline the corresponding measure of effectiveness (i.e., target engagement time by surface-to-air missile site). One or more parameters in the scenario solution were then changed (receiver dynamic range, jamming assignment, etc.) and the measures of effectiveness were re-derived in order to investigate their sensitivity to these changes. In addition, this project developed a User's Guide for the Naval Research Laboratory (NRL) Advanced Reactive Electronic Warfare Simulation (ARES) software Version 1.12 used in the analysis.

### PUBLICATION:

Pace, P.E., Wickersham, D., Jenn, D. and York, N., "High Resolution Phase Sampled Interferometry Using Symmetrical Number Systems," *IEEE Transactions on Antennas and Propagation*, Vol. 49, No. 10, pp. 1411-1423, October 2001.

### THESIS DIRECTED:

Pham, P.N., "Sensitivity Analysis of an Optimum Multi-Component Airborne Electronic Attack Configuration for Suppression of Enemy Air Defense," Masters Thesis, Naval Postgraduate School, March 2001. (Classified Secret)

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics, Modeling and Simulation

**KEYWORDS:** Electronic Attack, Network-Centric Warfare, Optimum Sensor Configuration, Measures of Effectiveness



## PROJECT SUMMARIES

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### PHOTONIC ADC ARCHITECTURES FOR MICROWAVE SIGNAL COLLECTION AND ANALYSIS

**Phillip E. Pace, Professor**

**John P. Powers, Distinguished Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Defense Advanced Research Projects Agency**

**OBJECTIVE:** The objective of this proposal is the experimental investigation of a phototonic architecture for high-speed sampling and digitalization of RF and microwave signals.

**SUMMARY:** The proposed effort consists of three options for funding level (per sponsor request). The photonic ADC used a mode-locked laser to oversample an input signal at two mach-zehnder interferometers. A fiber lattice accumulator is embedded within a feedback loop around a single-bit quantizer to spectrally shape the quantization noise to fall outside the signal band of interest. Decimation filtering is applied to the quantizer output to construct the input signal with high resolution. It was proposed to investigate the following: The effects of non-uniform sampling (JITTER), the accumulator leakage resulting from a mismatch in optical circuit parameters, the spurious free dynamic range, signal-to-noise plus distortion ratio AND effective number of bits for several oversampling ratios.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Sensors, Sampling, Electro-Optic, Photonics

### REVOLUTION IN BATTLESPACE TECHNOLOGIES WORKSHOP 2001

**Phillip E. Pace, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Swedish National Defense College**

**OBJECTIVE:** This 3-week course hosted by the NPS Center for Joint Services Electronic Warfare, is intended for international military officers and technical research personnel who are interested in the technologies of command and control warfare (C2W).

**SUMMARY:** The course was sponsored by the Swedish National Defence College (SNDC), and ordered through the Security Assistance Office at the American Embassy in Stockholm under MASL P179220. This year, the workshop was held from April 23 through May 11, 2001. A total of 31 NDC students and eight supporting SNDC staff (including Brigadier General Bjorn Andersson) attended the workshop. All course materials and textbooks were supplied to the students. During the first week there was an Opening Reception and a photo taken of all participants in the course. A field trip to Condor Systems was also taken during the second week. A Flag Dinner and Graduation Ceremony and Dinner were held in week three. Upon completion of the course, students received a Certificate of Graduation. All course materials were mailed back to SNDC upon completion of the course.

#### **PUBLICATION:**

Pace, P.C., "Advanced Technical Workshop 2001: Revolutions in Battlespace Technology," Center for Joint Services Electronic Warfare, Volumes I-IV, 23 April–11 May 2001.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics, Modeling and Simulation

**KEYWORDS:** Workshop, Short Courses, Technology, NPS Center For Joint Services Electronic Warfare

## PROJECT SUMMARIES

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### ELECTRONIC WARFARE ADVANCED TECHNOLOGY STUDIES

**R. Clark Robertson, Professor**

**Ron Pieper, Visiting Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsors: Naval Air Warfare Center**

**OBJECTIVE:** The objective of this project was to determine IRCM effectiveness for the F/A-18-E/F for both a smart and a dumb SA threat and a smart AA threat with both straight and level flight as well as maneuvering. In addition, the results obtained with an area source model were to be compared to those obtained with the SPIRITS model.

**SUMMARY:** The objective of this study was to evaluate MOSAIC based counter-measure predictions for the F/A-18-E/F platform. Various questions were addressed, such as:

1. Do maneuvers when combined with flare drops produce an overall countermeasure improvement for the F/A-18-E/F?
2. Do changes in atmospheric conditions and platform altitude tend to enhance or diminish countermeasure effectiveness?
3. Do the "area" source miss distance results differ significantly with predictions generated using the SPIRITS model? Also, can the percentage of cases in which models disagree as to whether the simulation ends in hit or miss be established?

These questions were addressed for an experimental matrix using various flare salvos, aircraft altitudes, aircraft speeds, and missile types, both surface-to-air and air-to-air. This project is ongoing and will conclude in March 2002.

#### **PRESENTATION:**

Robertson, C., "IRCM Effectiveness for the F/A-18-E/F," PMA-272, Patuxent River, MD, October 2001.

#### **THESIS DIRECTED:**

Lott, B., "IRCM Effectiveness for the F/A-18-E/F," Masters Thesis, Naval Postgraduate School, March 2002.

**DoD KEY TECHNOLOGY:** Electronic Warfare

**KEYWORDS:** Electronic Countermeasures, IR Countermeasures, IR Sensors

### BEARTRAP POST-MISSION ANALYSIS SYSTEM

**Murali Tummala, Professor**

**Charles W. Therrien, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Advanced Maritime Program Office, Naval Air Station - Patuxent River**

**OBJECTIVE:** To design and develop a signal processing system capable of implementing narrowband frequency tracking, multi-target tracking, wideband and related processing, time-domain analysis, and data fusion for Beartrap post-mission analysis or S2K (for System 2000).

**SUMMARY:** During 2001, the project was not funded and the activity has been phased out and transferred to the Beartrap site at Brunswick, Maine. The beta testing of the software delivered during 2000 is being carried out at designated sites. The principal investigators are no longer involved in the project.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Computing and Software, Human Systems Interface, Other (Signal Processing)

**KEYWORDS:** Signal Processor Design, Acoustic Signal Processing, Graphical User Interface Design

## PROJECT SUMMARIES

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### **JSIPS-N COMMUNICATIONS ARCHITECTURE MODELING AND SIMULATION**

**Murali Tummala, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Aviation Depot - Cherry Point**

**OBJECTIVE:** To develop a simulation model for JSIPS-N packet switched communications network, including local and wide area segments and other network components. Issues to be addressed in this effort are performance indicators, assessment of alternate network topologies and system constraints in terms of capacity limitations and maximum number of sites supportable.

**SUMMARY:** This work produced a baseline model of the Joint Services Image Processing System – Navy Communications system. The model was designed with future expansion in mind, thus it can be used as a design tool and as a means to simulate operational performance prior to making actual design modifications on the network. It can also serve as a management tool to identify areas that require improvement or upgrades. The results illustrate how the baseline model can be used to simulate various operating scenarios. The model was successful in evaluating the overall performance of the system and provided significant data on areas that may require upgrading or configuration improvement.

**THESIS DIRECTED:**

Hootman, J., “JSIPS-N Baseline Architecture Simulation and Performance Evaluation,” Masters Thesis, Naval Postgraduate School, in progress.

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications

**KEYWORDS:** Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

### **JOINT TACTICAL RADIO SYSTEM (JTRS) AND DIGITAL MODULAR RADIO**

**Murali Tummala, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Center - San Diego**

**OBJECTIVE:** To develop graduate level course materials for wireless networks with emphasis on software defined radio principles and in support of the digital modular radio program. As part of the work, also investigate the mobile ad hoc routing protocols for use in the DMR program.

**SUMMARY:** The effort to develop materials for a course on wireless networks and software-defined radio continued during 2001. The routing protocols have been investigated for mobile ad hoc networks: distributed source routing. The effects of the data link, network, and transport level protocols on the quality of real-time data have been studied.

**THESIS DIRECTED:**

da Silva Mattos, L., “Quality-of-Service Schemes for Mobile Ad-Hoc Networks,” Masters Thesis, Naval Postgraduate School, March 2001.

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications, Computing and Software

**KEYWORDS:** Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

## PROJECT SUMMARIES

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### QUALITY-OF-SERVICE IN MOBILE AD HOC NETWORKS

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center - San Diego

**OBJECTIVE:** Develop algorithms for quality-of-support assurance in mobile ad hoc networks. Traffic conditioning, marking, and buffer management have been investigated to provide quality of service assurance for real-time traffic in JTRS like environments.

**SUMMARY:** To achieve QoS, independently of the routing protocol, each mobile node participating in the network must implement traffic conditioning, traffic marking and buffer management or queue scheduling schemes. In MANETs, since the mobile nodes can have simultaneous multiple roles, it was found that traffic conditioning and marking must be implemented in all mobile nodes acting as source nodes. Buffer management and queue scheduling schemes must be performed by all mobile nodes. QoS schemes for different types of traffic, geographical areas of different sizes and various mobility levels have been simulated and their performance studied. Metrics, such as throughput, end-to-end delay and packet loss rates, were used to measure the relative improvements of QoS-enabled traffic sessions. The results indicate that in the presence of congestion, service differentiation can be achieved under different scenarios and for different types of traffic whenever a physical connection between two nodes is realizable.

#### THESIS DIRECTED:

da Silva Mattos, L., "Quality-of-Service Schemes for Mobile Ad-Hoc Networks," Masters Thesis, Naval Postgraduate School, March 2001.

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications

**KEYWORDS:** Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

### RF DISTRIBUTION SYSTEMS AND DMR INTEROPERABILITY

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center - San Diego

**OBJECTIVE:** To provide research and development support for the digital modular radio procurement program. Issues to be addressed in this effort are integration of distribution systems and interoperability with the digital modular radio system.

**SUMMARY:** The work consisted of two phases: conducting research to investigate algorithms to provide better traffic management in DMR like environments and interacting with the sponsor and participating in planning and review meetings to assess the interoperability and system procurement. Active queue management mechanisms for real-time traffic for DMR like environments have been developed. A new algorithm called selective early discard (SED) that selectively drops packets in order to spread the packet losses in a queue has been proposed. Using simulation, the new schemes are evaluated in a MANET environment, and their performance is compared with other existing QoS schemes. Results indicate that SED minimizes the burst errors due to buffer overflow, thereby improving the performance for real-time traffic. SED is also capable of providing service differentiation; additional performance improvement can be realized by utilizing timestamps.

#### THESIS DIRECTED:

Fountanas, L., "Active Queue Management Mechanisms for Real-Time Traffic in MANETs," Masters Thesis, Naval Postgraduate School, December 2001.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications

**KEYWORDS:** Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

**SIGNAL-TO-NOISE ENHANCEMENT PROGRAM**  
**Wilbur R. Vincent, Associate Research Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Security Group**

**OBJECTIVE:** To define factors that adversely affect signal reception at receiving sites, determine the primary characteristics of factors, identify all factors, and provide recommendations for effective mitigation actions.

**SUMMARY:** Radio noise from overhead power lines has been identified as the major factor limiting the reception of radio signals at 36 of 37 sites examined. This little recognized factor is seriously limiting the effectiveness of HF, VHF, and UHF intercept systems to collect signals of special interest. The primary properties of this noise have been defined, source location procedures have been devised, and a means to identify source hardware has been generated. This effort has generated a number of technical papers and presentations during the last year. Some related work on signal reception in the microwave ISM bands has also been conducted.

### **PUBLICATIONS:**

Parker, A.A., Adler, R.W. and Vincent, W.R., *Conducted EMI from an Engineering Model of DC-to-DC Converter*, Naval Postgraduate School Technical Report, NPS-EC-01-007, June 2001.

Melnick, C., Munsch, G. and Vincent, W., "Signal Reception Survey and Site LZO," prepared for National Security Agency with assistance from Argon Engineering Associates.

### **PRESENTATIONS:**

Vincent, W., Adler, R. and Munsch, G., "A Review of Man-Made Radio Noise at 37 HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Munsch, G. and Adler, R., "A Progress Report on a Model for Man-Made Noise at HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Parker, A., Adler, R. and Vincent, W., "Spectrum Signatures of Man-Made Noise," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Parker, A. and Adler, R., "Ambient Signals and Noise in the 915-MHz ISM Band," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "Operation of a 2.4 GHz Portable Phone with Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "The Temporal and Spectral Properties of Radio Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

## PROJECT SUMMARIES

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### OTHER:

Parker, A., Adler, R. and Vincent, W., "Parasitic Oscillations from an Active Television Antenna," prepared in cooperation with the Department of Oceanography, Naval Postgraduate School.

Vincent, W. and Munsch, G., "Power-Line Noise Mitigation Handbook for Naval and Other Receiving Sites," draft of 5<sup>th</sup> edition. (This handbook was extensively updated during the 2001 and it will be published in early 2002.)

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Radio Noise, Interference, Spectrum Signatures

### FIRST PRINCIPLES PREDICTION OF X-RAY IMPULSE

Donald van Z. Wadsworth, Senior Lecturer

Department of Electrical and Computer Engineering and Space Systems Academic Group

Sponsor: Navy Strategic Systems Programs Office

**OBJECTIVE:** The multi-year objectives are: (i) collect and archive key data (reports and interviews) relevant to predicting the vulnerability of an RB aeroshell to an xray burst in space, (ii) compare the capability of existing physics-based models (finite-element hydrocodes and radiation deposition codes) to predict blow-off impulse and damage to various RB composite materials, (iii) modify a selected code to improve fidelity, (iv) validate the modified code against existing test data (UGT and AGT) and, if needed, plan and execute new tests using existing facilities (flash xray and surface loading), (v) establish a continuing core effort at NPS in support of SSP, involving faculty, graduate students, and coordination with related efforts at the DoE National Laboratories, DTRA, NNSA, NRL, and AFRL.

**SUMMARY:** Field trips to SSP headquarters, DTRIAC, and the National Laboratories (LANL, SNL, LLNL) resulted in a mine of documents covering the extensive restricted work in this field during the past 30 years. This together with extensive discussions with the experts at the various laboratories provided an ideal starting point for this project. With the support of key personnel at LLNL, as well as a Navy Master's Degree Thesis student and Professor Don Danielson (NPS Applied Mathematics Department), a weapons code was utilized to evaluate the shock impulse to a representative aeroshell due to a standard nuclear ABM threat model. Professor Knox Milsaps, Mechanical Engineering Department, is the co-advisor for the thesis.

After significant difficulty due to the different security organizations in DoE and DoD, DoE clearances were obtained for all involved and a classified mail channel was opened between LLNL and NPS, which is proving invaluable in pursuing this research project.

Installation at NPS of the SNL finite element hydrocode, CTH, was begun and will be evaluated during CY2002. Professor Danielson examined the commercial hydrocode, DYTRAN, for use in this project. Both CTH and DYTRAN will require addition of a radiation deposition module. A start was made in determining the suitability of using the NPS electron-beam machine for validating selected modeling code predictions. SNL colleagues suggested using their Z-pinch machine as a flash x-ray source for radiating aeroshell samples which were obtained from the SSP contractor.

**DoD KEY TECHNOLOGY AREA:** Other (Nuclear Weapons Effects, Hydrocodes)

**KEYWORDS:** Nuclear Weapons, X-Ray Radiation, Thermomechanics

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## PROJECT SUMMARIES

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### **SILVACO TOOLS DEVELOPMENT FOR RADIATION EFFECTS**

**Todd Weatherford, Assistant Professor**

**Andrew Parker, Research Associate**

**Department of Electrical and Computer Engineering**

**Sponsors: Naval Surface Warfare Center – Crane Division**

**OBJECTIVE:** To develop semiconductor simulation tools to improve modeling of radiation effects in semiconductor devices.

**SUMMARY:** Work in 2001 has continued on modeling radiation effects in Metal-Oxide-Semiconductor Silicon-on-Insulator (SOI) structures and charge trapping in buried oxides. The SOI modeling has been expanded to examine radiation effects on sense amps and analog circuitry for ferroelectric memories. Additional duties to test, model and design radiation hardened InGaAs photodetectors for InteFermetric Optical Guidance (IFOG) systems. A third project included in this research included the addition of characterizing ferroelectric capacitors.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles, Electronics, Materials, Processes and Structures, Modeling and Simulation

**KEYWORDS:** Electronics, Materials, Processes and Structures, Modeling and Simulation, Silicon-on-Insulator

### **SUPPORT FOR THE NPS LINEAR ACCELERATOR (LINAC)**

**Todd Weatherford, Assistant Professor**

**Andrew Parker, Research Associate**

**Department of Electrical and Computer Engineering**

**Sponsors: Various Activities**

**OBJECTIVE:** Provide operation of the NPS LINAC and Flash X-ray facilities to internal and external users to study radiation effects in semiconductors and other materials.

**SUMMARY:** In 2001 both facilities have been maintained and improved for dosimetry. Over eight outside firms and three NPS researchers have utilized the facilities in CY01. The facilities have supported reimbursable research, which include student master theses.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles, Electronics

**KEYWORDS:** Radiation Effects, Electronics, Particle Accelerators, Materials, Semiconductors

### **AEA ARCHITECTURE AND PLATFORM MIXES**

**Lonnie A. Wilson, Research Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Air Systems Command**

**OBJECTIVE:** The objective is to perform top level analysis of AEA (Advanced Electronic Attack) Architecture and Platform Mixes and identify key capabilities and needs to support the OSD AEA EA -6B follow-on studies.

**SUMMARY:** The EA -6B service life is through 2015–2020 requiring a follow-on platform or platform mix to the ICAP III upgrade expected to IOC in 2004. These efforts used the EA -6B ICAP III as a baseline to build a future Electronic Attack (EA) capability to accomplish the SEAD role and other Information Operation missions. This core tactical capability includes radar jamming, communication jamming, hard-kill capabilities, and connectivity to ISR and offboard assets. The expected results were a platform mix utilizing available technology to develop a system of systems to provide future EA capabilities.

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## PROJECT SUMMARIES

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AEA candidate air vehicles are manned or unmanned, performing either the dedicated AEA role or having AEA capability as part of their multi-mission capability. The nature of AEA support requires detailed knowledge of the supported air, ground and sea forces and emerging warfighter concepts in Information Operations (IO).

The fundamental goal of the AEA was to find the most mission capable, cost effective solution to tactical aviation requirements for electronic warfare (EW) support. The initial requirement is driven by the necessity to replace an aging EA -6B airframe.

The architecture and preliminary design were completed for a digital ES (Electronic Support) receiver and processor for the AEA application. Technical performance improvements and new operational performance capabilities were identified. The AEA Technical Working Group agreed to develop the digital EC receiver along with high performance DSP with Specific Emitter Identification. NPS participated and supported the AEA Technical Working Group, the Digital Receiver Focus Group and the SEI Focus Group.

A new digital match filter concept was developed and demonstrated for the high performance detection and processing of LPI radar signals.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Other (Radar, Strike, and Surveillance)

**KEYWORDS:** EW, EA, Architecture, F-18G, UAV, UCAV, and IW

### **ELECTROMAGNETIC SUSCEPTIBILITY AND ANALYSIS OF CRITICAL INFRASTRUCTURE SYSTEMS**

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Engineering Logistics Office**

**OBJECTIVE:** The basic objective is to research the electromagnetic susceptibility of critical infrastructure systems.

**SUMMARY:** The research started the electromagnetic susceptibility and analysis of critical infrastructure systems. This initial research included the EM susceptibility and analysis for one infrastructure system.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Other (Information Warfare)

**KEYWORDS:** Electromagnetic, Radar, Electronic Warfare, IW

### **HIGH PERFORMANCE ELINT DEINTERLEAVER DEVELOPMENT**

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** The basic objective is to develop a High Performance ELINT Deinterleaver (with contamination screening and deinterleaving processing) using classical and intrapulse parameters. This development builds on previous efforts including key technical feasibility demonstrations for High Performance ELINT SEI Processor.

**SUMMARY:** The NPS Deinterleaver is conceptually divided into two parts: 1) Preprocessor Section and 2) Deinterleaver Processor. Inputs to the deinterleaver include digitized IF from either pre-recorded standard data sets or operational feeds. Also, the Deinterleaver accepts optional AOA and TOA data.

Deinterleaver outputs include sorted Pulse Word Trains or Pulse Bursts to the SEI association algorithms. Also, deinterleaver pulse numbers and pulse parameter sets are passed to the IF Pulse Data Distribution for recording purposes, if desired.

From a single pulse, parameter estimates include: frequency, TOA, AOA, pulsewidth, risetime, amplitude modulation on pulse, phase modulation on pulse, frequency modulation on pulse, peak



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amplitude, pulse peak power, noise power, SNR. Also, interpulse parameters are derived from single pulse parameter information. Interpulse parameters include PRF, Scan and other parameters.

The Preprocessor Section includes: Digital Pulse Detection, Pulse Saturation and Minimum SNR Screen, Average Carrier Frequency Tune Error and Gross Interference Screen. The Deinterleaver Processor includes classical and MOP (intrapulse signals) Parameter Extractions, and Deinterleave Unit.

The Deinterleaver algorithms include classical and Modulation on Pulse (MOP) parameter extractions in the optimal characterization bandwidth, assignment of confidence to all measured parametrics, and a data formatting process. Angle of Arrival (AOA) centroiding and multi-channel complex voltage conjugates (phase & amplitude) will only be done in future development tasks. The NPS implementation has a single channel capable of batch processing output records to associate pulse descriptor words into bursts and trains using MOP parametrics and classical parameters, with confidence factors.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Sorting, ID, RF Receiver, MOP Signal Extraction, Parameter Extraction, Targeting

### NPS STUDENT AND FACULTY HIGH POWER MICROWAVE (HPM) RESEARCH

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Research Laboratory**

**OBJECTIVE:** The basic objective of this research is to continue development of high power microwave (HPM) and ultra-wideband (UWB) technology and capabilities research at the Naval Postgraduate School including source and systems engineering and design, modeling and simulation and effects testing. This work will have application to ship defense, information warfare/information operations (IW/IO), and human-computer interface (HCI).

**SUMMARY:** Critical Infrastructure Protection (CIP) developments were performed using basic technology analysis and fundamental signal processing considerations for one infrastructure system. The NPS research used multiple signals from a specific electronic environment. SPY-1 radar and other radars were considered in the selected receiver system and processing results were analyzed.

**DoD KEY TECHNOLOGY AREA:** Human Systems Interface, Modeling and Simulation

**KEYWORDS:** HPM Source, Systems, Wideband, IW, IO

### MOTION TRACKING USING INERTIAL SENSORS

**Xiaoping Yun, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Chief of Naval Operations (N6M) and Army Research Office**

**OBJECTIVE:** To develop a hybrid inertial/magnetic body tracking system for use in a networked virtual environment.

**SUMMARY:** An improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System was designed and implemented. The current MARG Body Tracking System is limited to tracking three limb-segments. The MARG sensors are physically connected to a desktop computer by cables. In this year, a multiplexing circuit was implemented to allow tracking of 15 limb-segments. Processing was moved from a desktop computer to a wearable computer and wireless communication was implemented using an IEEE 802.11b spread spectrum wireless LAN. The resultant system is able to track the entire human body and is untethered. The range of the system is the same as that of the wireless LAN which can be extended with the use of repeaters.

The second effort of this project was to develop a realistic human avatar to be interfaced with the MARG sensor system. With the continuing gain in computing power, bandwidth, and Internet popularity

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there is a growing interest in Internet communities. To participate in these communities, people need virtual representations of their bodies, called avatars. Creation and rendering of realistic personalized avatars for use as virtual body representations is often too complex for real-time applications such as networked virtual environments (VE). Virtual Environment (VE) designers have had to settle for unbelievable, simplistic avatars and constrain avatar motion to a few discrete positions. The approach taken in this project is to use a full-body laser-scanning process to capture human body surface anatomical information accurate to the scale of millimeters. Using this 3D data, virtual representations of the original human model can be simplified, constructed and placed in a networked virtual environment. The result of this project is to provide photo realistic avatars that are efficiently rendered in real-time networked virtual environments. The avatar is built in the Virtual Reality Modeling Language (VRML). Avatar motion can be controlled either with scripted behaviors using the HAnim specification or real-time data from the MARG sensors. Live 3D visualization of animated humanoids is viewed in freely available web browsers.

### PUBLICATIONS:

Marins, J.L., Yun, X., Bachmann, E.R., McGhee, R.B. and Zyda, M.J., "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 2003-2011, Maui, HI, 29 October-3 November 2001.

Bachmann, E.R., McGhee, R.G., Yun, X. and Zyda, M.J., "Inertial and Magnetic Posture Tracking for Inserting Humans into Networked Virtual Environments," *ACM Symposium on Virtual Reality Software and Technology (VRST'01) Proceedings*, pp. 9-16, Banff, Alberta, Canada, 15-17 November 2001.

### THESES DIRECTED:

Hollis, P.G., "An Improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System," Masters Thesis, Naval Postgraduate School, June 2001.

Dutton, J.A., "Developing Articulated Human Models from Laser Scan Data for Use as Avatar in Real-time Networked Virtual Environments," Masters Thesis, Naval Postgraduate School, September 2001.

Aljuaied, A.M., "Bluetooth Technology and Its Implementation in Sensing Devices," Masters Thesis, Naval Postgraduate School, September 2001.

### DoD KEY TECHNOLOGY AREA: Sensors

**KEYWORDS:** Motion Tracking, Inertial Sensors, Human Avatar, Wireless LAN

### REDUCED CREW SIZE METROLOGY USING WIRELESS LANs AND WEARABLE PCs

Xiaoping Yun, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center

**OBJECTIVE:** To investigate the Reduced Crew Size (RCS) Metrology using WLANs and wearable computers.

**SUMMARY:** Working with the Measurement Science Directorate (MSD) of the Naval Surface Warfare Center (NSWC-Corona), feasibility of developing a general purpose calibration system using wearable computers and wireless LANs was studied. In particular, a prototype of pressure calibration system has been developed. The system includes a software module that makes it possible to submit calibration data to a remote server using wired or wireless LAN. The prototype system was demonstrated at the Fleet Maintenance Symposium at San Diego on 27-29 August 2001.

## PROJECT SUMMARIES

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### THESIS DIRECTED:

Ly, T.T., "Shipboard Wireless Network Applications," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Metrology, Wireless LAN, Wearable Computer

### SUBMARINE WIRELESS LOCAL AREA NETWORKING

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**Sponsor: Naval Sea Systems Command**

**OBJECTIVE:** To test and evaluate IEEE 802.11b compliant wireless LAN product components with respect to EMI/EMC for submarine damage control communications.

**SUMMARY:** A preliminary EMC study of COTS wireless LAN components was conducted. The difference between FCC Part 15 requirements and MIL-STD-461E requirements was investigated. It was noted that FCC Part 15 restrictions for radiated emissions are more stringent in the frequency ranges of 2.4 GHz and higher as compared to MIL-STD-461E. It was also noted that FCC Part 15 lacks sufficient requirements for susceptibility. Four tests of MIL-STD-461E (CE102, RE102, CS101, RS103) were conducted on the Aironet 4800 DS wireless LAN components. These four tests represent one in each of the required testing areas: conducted emissions, radiated emissions, conducted susceptibility, and radiated susceptibility. Based on these limited tests, it appears that the Aironet 4800 series of wireless LAN components are electromagnetically compatible with the submarine systems.

A Java based application for Damage Control (DC) communications was developed. The application uses multicast sockets to send standard DC and crew reports from handheld devices to the DCC console (see figure below) wirelessly.

OPNET Modeler 7.0B was used to produce a simulation of the proposed Virginia Class wired/wireless network, in the presence of a type load. The creation of a detailed 24-hour workload includes various combinations of HTTP, FTP, EMAIL, DB and Audio and Video to accomplish their tasks. This full workload was then applied to the built OPNET simulation. Subnet-to-Subnet throughput and application response time graphs show that the designed network would work well. Sensitivity analysis was also performed to determine when this system would fail by progressively increasing the full workload factor. This analysis showed that the system performs satisfactorily up to 152 wireless clients (each carrying a full workload). To provide an extra layer of validity to the simulation, an analytical model was developed for the longest path scenario and the Ethernet delay was compared. The results showed the simulation to be accurate based on similar Ethernet delays.

### THESES DIRECTED:

Peck, E.A., "Analysis and Evaluation of the Electromagnetic Compatibility of COTS Wireless LAN Components Onboard Submarines," Masters Thesis, Naval Postgraduate School, September 2001.

Wilkins Jr., W.G., "Concepts, Applications and Analysis of a Submarine Based Wireless Network," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREA:** Command, Control and Communication

**KEYWORDS:** Damage Control, Wireless Computer Networks

## PROJECT SUMMARIES

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### COMPUTER AIDED DETECTION FOR THE SYNTHETIC APERTURE SONAR SYSTEM

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Sponsor: Naval Sea Systems Command

**OBJECTIVE:** Derive accurate equations that will allow one to compute the probability of detecting a mine-like- object (MLO) for a given probability of false alarm (false-alarm rate) for a given ocean environment. Work will begin on deriving an expression for the signal-to-interference power ratio (SIR) at the output of a correlator receiver that will take into account the propagation in the ocean medium of an acoustic signal from the transmit array to the target, and from the target back to the receive array. The probability of detection can be related to both the probability of false alarm and the SIR. Efforts will be made to express the SIR in terms of the complex scattering amplitude functions of different types of mines and ocean bottoms, and in terms of “target” and “reverberation” ambiguity functions.

**SUMMARY:** A set of pulse-propagation coupling equations was successfully derived. They couple the output electrical signal at a point element in a receive array to the transmitted electrical signal at the input to a transmit array via the complex frequency response of a fluid medium (e.g., air or water). The pulse-propagation coupling equations are based on linear, time-variant, space-variant, filter theory, the principles of complex aperture theory and array theory, and solving a linear wave equation, which includes satisfying all boundary conditions, including the boundary condition at the source. The time-variant, space-variant, complex frequency response of the ocean was shown to be the time-harmonic solution of a linear wave equation when the source distribution is a time-harmonic point source.

The pulse-propagation coupling equations provide a consistent, logical, and straightforward mathematical framework that can be used to accurately model the propagation of small-amplitude acoustic pulses in the ocean for a bistatic scattering problem. The main features of the pulse-propagation coupling equations are as follows: 1) transmitted electrical signals are modeled as amplitude-and-angle-modulated carriers, 2) both the transmit and receive apertures are modeled as volume, conformal arrays composed of unevenly-spaced, complex-weighted, point elements (this type of model for both of the apertures allows for maximum flexibility), 3) the complex weights are frequency dependent and allow for beamforming, 4) the performance of the point elements in both the transmit and receive arrays are characterized by frequency-dependent, transmitter and receiver sensitivity functions, and 5) the solution of a linear wave equation is given by the complex frequency response of the fluid medium. It is important to note that attention to all proper units of measurement were taken into account in order to ensure the accurate prediction of signal strength levels at each element in a receive array. This is especially important, for example, in order to obtain accurate probability of detection results.

Derivations of the complex frequency response of the ocean for the following three different bistatic scattering problems were performed: 1) no motion, 2) only the discrete point scatterer is in motion, and 3) all three platforms (the transmitter, discrete point scatterer, and receiver) are in motion. Specific examples on the use of the pulse-propagation coupling equations were given for the three different bistatic scattering problems. Scatter from a discrete point scatterer was modeled via the scattering amplitude function, which is a complex function (magnitude and phase) and is, in general, a function of frequency, the direction of wave propagation from the source to the scatterer, and the direction of wave propagation from the scatterer to the receiver. In addition to the scattering amplitude function, frequency-dependent attenuation was taken into account in order to model the propagation of sound from transmitter to discrete point scatterer, and from discrete point scatterer to receiver. The dimensionless, time-compression/time-stretch factor was derived and discussed for the two bistatic scattering problems involving motion. The time-compression/time-stretch factor takes into account the relativistic effects of motion and provides for accurate time delay and Doppler shift values.

#### PUBLICATION:

Ziomek, L.J., *Pulse Propagation and Bistatic Scattering*, Naval Postgraduate School Technical Report, NPS-EC-02-001, 26 October 2001.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Detecting Mine-Like Objects, Signal-to-Interference Power Ratio, Target Ambiguity Functions, Reverberation Ambiguity Functions